UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A COMPUTER-CONTROLLED AUTOMATED STORAGE AND RETRIEVAL SYSTEM

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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June 2008

Chairman: **Professor Ir. Norman Mariun, PhD**

Faculty: **Engineering**

Industrial demands for higher productivity require the replacement of the traditional control equipment with newer solutions that take advantage of the latest technologies. Programmable Logic Controllers (PLCs) based system has been the main choice for control equipments for the last decades. With the rapid advancement of computing technologies, the importance of PC-based system increased remarkably in the last few years. Retrofitting the PLC based system with the PC-based system offers many advantages. Among these advantages are PC-based systems are more flexible, easy integration, lower costs, better human machine interface (HMI) facilities. The implementation of a PC based motion control on a three-axis ASRS system is the main focus of this work. The scope of the work covers the implementation of two hardware platforms for the proposed system and to implement PID system on the two platforms. The development of

GUI for the ASRS system provides the users with a comprehensive and user friendly interface to control the system. The performances of two types of hardware platforms; PCI 7344 motion controller card and (FP) 2000 Field point is compared based on trapezoidal motion profile. Both platforms are controlled by a proportional-integral-derivative (PID) controller. The parameters for the controller are determined experimentally. The experimental results show that both platforms successfully tracked the motion profile, and the tracking performance improves as the velocity of the system increase. Overall this work shows that PC-based system offers many advantageous to control and ASRS system.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Sarjana Sains

PEMBANGUNAN KAWALAN GERAKAN SISTEM ASRS BERASASKAN KAWALAN KOMPUTER

Oleh

SA'DIAH JANTAN

June 2008

Chairman: **Professor Ir. Norman Mariun, PhD**

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Keperluan untuk meningkatkan produktiviti disektor industri memerlukan suatu sistem kawalan berdasarkan teknologi terkini bagi mengantikan sistem kawalan tradisional. Sistem kawalan berasaskan PLC merupakan pilihan utama industri sejak beberapa dekad lalu. Kepentingan sistem kawalan berasaskan komputer peribadi meningkat dengan mendadak kebelakangan ini sejajar dengan perkembangan teknologi komputer berbanding dengan PLC, sistem kawalan berasaskan komputer mempunyai beberapa kelebihan seperti sistem yang lebih fleksibel, kos yang lebih rendah, tiada kekangan hakmilik dan penghubungan sistem antaramuka manusia dan mesin yang lebih baik. Implementasi kawalan berasaskan komputer peribadi terhadap sistem berautomasi tiga-axis ASRS menjadi fokus kajian ini. Pembangunan GUI di dalam kajian ini memberikan kemudahan komprehensif kepada pengguna untuk mengawal sistem tersebut.

Prestasi bagi sistem kawalan berasaskan komputer berdasarkan PCI 7344 dan dasar FP 2000 telah diimplementasikan dalam kajian ini dengan kawalan PID. Parameter PID telah dikenalpasti melalui kajian. Kajian menunjukkan kedua-dua dasar tersebut telah memberikan respon yang baik terhadap profil trepizoid. Secara keseluruhan, sistem berasaskan komputer menawarkan banyak kebaikan terhadap kawalan pergerakan sistem ASRS.

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Finally, I dedicate this undertaking to my husband, Dr. Mohd Sobri Takriff and our children. Thanks for their endless support, patience and understanding during these years.

I certify that a Thesis Examination Committee has met 6 June 2008 to conduct the final examination of Sa'diah Jantan on her thesis entitled "Development of a Computer-Controlled Automated Storage and Retrieval System " in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

SA'DIAH JANTAN

Date: 22 December 2008

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LIST OF ABBREVIATIONS

AC	Alternating Current
ADRC	Active Disturbance Rejection Controller
ASRS	Automated Storage and Retrieval System
DC	Direct Current
DSP	Digital Signal Processing
ELCB	Earth Leakage Circuit
FMS	Flexible Manufacturing System
FP	Fieldpoint
GPOS	General Purpose Operating System
GUI	Graphical User Interface
I/O	Input Output
MAX	Measurement and Automation Explorer
MCB	Miniature Circuit Breaker
Mm	Millimeter
NI	National Instrument
OS	Operating System
PC	Personal Computer
PCI	Peripheral Connections Interface
PI	Proportional-Integral
PID	Proportional-Integral-Derivative
PLC	Programmable Logic Controller
PRBS	Pseudo-Random Binary Sequence
QUAD	Quadrature
RAM	Random Access Memory
RPM	Revolution per minute
Rps	Revolution per second
RTOS	Real-time operating systems
SID	System Identification
SR	Storage Retrieval

UMI	Universal Machine Interface

LIST OF SYMBOLS

Acc	Acceleration
A	Acceleration
Dec	Deceleration
D	Deceleration
e_m	Position error
E	Profile
F_A	Axial Load
F_R	Radial load in Newton
$H(s)$	Transfer function of a system
I	Rated current
I_0	Continuous output current
I_{max}	Maximum output current
J_1	Inertia of pulley 1
J_2	Inertia of pulley 2
J_m	Rotor inertia
k_c	Proportional gain
k_u	Critical gain with P controller only
K_a	Amplifier gain
K_d	Derivative gain of the PID controller
K_f	Feedback gain
K_i	Integration gain of the PID controller
K_p	Proportional gain of the PID controller
K_s	Laplace transform of a transfer function
M	Weight
M_c	Mass of the box
n	Rated speed
P	Power capacity

P_0	Rated output
P_S	Rated power rate
R	Radius
R	Reference
S	Position
S_{acc}	Distance of acceleration
S_{dec}	Distance of deceleration
$S_{\max speed}$	Position at maximum speed
t_1	Acceleration time
t_2	deceleration time
t_u	Oscillation period with P controller only
T	Rated torque
T_d	Derivative time
T_i	Integral time
T_g	Motor torque
T_r	Rise time
T_s	Settling time
u_c	Control loop input
V	Voltage
y	Process output
y_f	Final output
y_r	Process command signal
α	Motor acceleration rate
Θ	Motor position
τ_m	Motor torque

CHAPTER 1

INTRODUCTION

1.1 Introduction

Personal computers (PCs) are widely used nowadays in automation systems. The achievement of such an interesting feature has been made possible due to the rapid growth of the computing technology, the availability of real-time operating systems and the development of programming languages suitable for control tasks [1]. PC-based system has been put forward in the automation in 1990's when programmable logic controller (PLC) based control which was an excellent tool in 1970's and 1980's was not designed for the commercial requirements [2] nor could it take the full advantage of the substantial electronics and software changes.

PC-based system offers several advantages over PLC-based system. They are easier to program and offer more flexibility and better performance [2-4]. With PC-based system, applications can be customized to meet current and future requirements, eliminating the needs to reinvest in a new system.

Motion control is defined as the precise control of anything that moves, and it is very essential in many industrial applications for its position and speed accuracy. It is usually designed to track trajectories and/or regulate about a desired point. Automation systems [5] include those that must integrate motion control to manipulate or move parts in production such as bar code reader for tracking and identifying components, visual inspection for quality assurance, etc [2]. Servomotor is the essential component of the motion control system, converting the electrical power from the servo drive into the mechanical power that moves the machine [6]. AC servomotor is most preferred in motion control over DC servomotor due to its brushless structure and no maintenance capability [1].

1.2 Background

Automated storage and retrieval system (ASRS), a three-axis system, is a major material handling support systems which has been an integral part of flexible manufacturing system (FMS) that have been widely used in automated factories and distribution centers. ASRS offers effective utilization of factory space, increase in productivity and reduce labor costs. It is based on a servo motion system. The performance of an ASRS can be measured by its positioning precision to track the motion profile and its throughput capacity which includes both SR machine travel time the time required to pickup or deposit a load and other times associated with SR machine operation.

Figure 1.1 shows all three-axes of the ASRS system used in this work. The traveling distance of *x-axis* is 1900 mm, *y-axis* is 560 mm, and *z-axis* is 1250 mm.

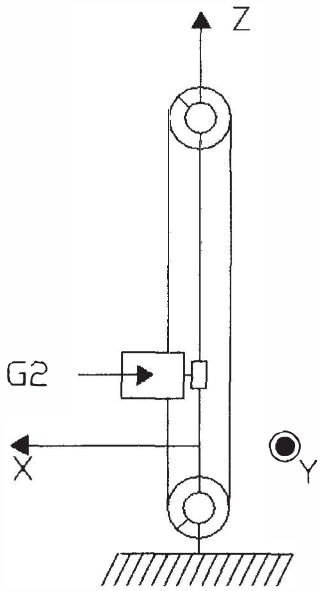

Figure 1.1: Three-Axis ASRS

1.3 Problem Statement

ASRS main purpose is to automatically depositing and retrieving loads from defined storage locations. Repeatable and accurate position of the loading box is critical as it affects the manufacturing process. The system should achieve high performance in terms of forcing the motion variable (position) to track the desired trajectory quickly and accurately. A system that could be maintained and easily updated based on modern control PC technology need to be developed.

1.4 Objectives of the Work

The main objective of this work is to implement a PC-based motion control on ASRS system. In order to achieve the objective, the following works were carried out.

1. Implement two types of hardware platform of the proposed system;
   a. PC-based system with National Instrument Motion card (PCI 7344)
   b. PC-based system with National Instrument Field point (FP 2000)
2. Implement a proportional-integral-derivative (PID) controller on both types of hardware platform onto the proposed system.

The second objective of the work is to evaluate the performance of the PC-based motion system based on trajectory motion profile.

1.5 Scope and Limitation

The development of the controller used in this work is applicable for a single stacker system with five rows and seven columns storage unit ASRS; the controller hardware and software used were National Instrument products since the product are robust and industrial standard.

1.6 Thesis Layout

This thesis consists of five chapters. The description of each chapter of this thesis is as follows.

- Chapter 1 presents the background of the work. It explains the introduction and the objectives of the work.

- Chapter 2 introduces the various basic concepts and reviews related to PC-based system, motion control, and the latest trends in motion control.

- Chapter 3 explains the construction and implementation of the proposed hardware. It starts with the implementation of two types of hardware platform follow by performance comparisons of the proposed system based on trajectory motion profiles.

- Chapter 4 discusses the results obtained from the work.

- Chapter 5 presents the conclusions and suggestions for further improvement of the proposed system.